Remarks

In the office action, the Examiner rejected claims 1-12, 15-17 and 19-21 under 35 USC 103 as unpatentable. Applicants disagree with the Examiner's basis for these rejections and in view of the foregoing amendments and following remarks, Applicants request reconsideration and withdrawal of the Examiner's rejections. Applicant respectfully submits that Claims 1-12, 15-17, and 19-21, as amended, are in condition for allowance.

Priority

Applicants petition to revive application number 10/140,316 has been granted. Accordingly, as the Examiner has indicated, the requirements of 35 USC 120 have been satisfied to establish that the subject application is a continuation of patent application serial number 10/140,316, which claims priority to U.S. Provisional Patent Application Serial No. 60/296,629 filed June 6, 2001.

Amendments to the Specification

Applicants' amendments to the specification are made to correct clear typographical errors. No new matter has been added by these amendments.

Claim Rejections – 35 USC 103

Independent Claim 1, as amended, recites a miniature combustor having a chamber wherein the chamber has "a lateral dimension traverse to a major flow direction within the chamber that is sub-centimeter" and "a means for forming a liquid film on the chamber's interior surface." The Examiner rejected claims 1-7 and 10-12 under 35 USC 103 as unpatentable over Schirmer USPN 2918118 ('118) and unpatentable over Meurer, and claims 8-9 under 35 USC 103 as unpatentable over Meurer in view of Schirmer USPN 3078672 ('672). Claim 1 is not

obvious over Schirmer '118 or Meurer as each of these cited references fails to teach or suggest an operable miniature combustor wherein at least one dimension of the combustor chamber is sub-centimeter and wherein the combustor includes a means for forming a film of liquid on the chamber's inner surface. Moreover, one of ordinary skill in the art would not turn to these references for a teaching relevant to the claimed invention as the operation of the apparatus of these references would tend to fail at the claimed dimensional limitations. See Declaration of Carlos Fernandez-Pello (hereinafter "Pello" Decl.) at ¶¶ 5 and 7-12 and Declaration of Paul Ronney (hereinafter "Ronney Decl.) at ¶¶ 5 and 7-12).

In general, size or dimensional limitations are not, by themselves, sufficient to patentably distinguish an invention over the prior art. However, if the size limitations would render the prior art systems or methods to fail, claimed size limitations may patentably distinguish an invention over the prior art because the size limitations make a significant difference in the operation of the prior art systems. *Gardner v. TEC Sys.*, 725 F.2d 1338, 1347, 220 USPQ 777 (Fed. Cir. 1984), *cert.* denied, 469 U.S. 830, 225 USPQ 232 (1984). In the present case, the prior art systems such as those disclosed in Schirmer '118 and Meurer, would not function at the sub-centimeter dimensions of the present invention. Id. The dimensional aspects of miniature combustion chambers create different phenomena which prevent the principles of larger combustion chamber systems from operating in smaller, miniaturized combustion chambers. Pello Decl. at ¶ 5; Ronney Decl. at ¶ 5.

At the claimed dimensions, i.e., sub-centimeter lateral dimension, which are comparable to known quenching distances, the surface-to-volume ratio for the combustion chamber is so large that a flame is typically not sustainable within the chamber due to the large heat transfer

losses to the chamber walls. To overcome this wall quenching phenomenon, the applicants teach and claim injecting a liquid, fuel or inert, as a film that covers the entire or substantially the entire area of the chamber walls. With a liquid film applied to and maintained on the chamber walls, the heat transferred from hot combustion gases is captured by the liquid film protecting the chamber walls and, thus, preventing substantial heat loss to the chamber walls. When the liquid is a fuel, the heat transferred from the hot combustion gases will serve to aid in vaporization of the liquid fuel so it is burned before it exits the chamber. Pello Decl. at ¶ 6; Ronney Decl. at ¶ 6.

Current technology for larger systems does not rely on liquid fuel filming on the chamber walls (though some fuel is intentionally vaporized from intake manifolds in IC engines as part of the charge preparation). Instead, to keep the ratio of liquid surface area to liquid volume large enough to sustain high fuel vaporization rates, the fuel is typically injected as a spray. The intention is to vaporize the liquid as a spray before very much liquid deposits on the walls or solid surfaces of the chamber. If the fuel were filmed in these larger engines or combustors, the surface area of the liquid would not be large enough to sustain the needed vaporization rate for combustion. Because the S/V ratio of any wall film will grow as the volume of the combustor decreases, the liquid fuel film in combustors in the sub-centimeter size range tends to provide a liquid surface area for vaporization comparable to a vaporizing spray. Furthermore, the liquid fuel film protects against heat losses at the wall and, thus, quenching, that a vaporizing spray does not. Simply scaling existing combustion systems down to the lateral dimensions taught and claimed would result in combustion failure due to quenching. Pello Decl. at ¶ 7; Ronney Decl. at ¶ 7.

Accordingly, it would not have been obvious to one of ordinary skill in the art at the time of the applicant's invention to have scaled the apparatuses of Schirmer '118 and Meurer to applicant's claimed dimensions. In combustors, dimensions cannot be simply scaled in proportion. The physics resulting from scaling a combustor's dimensions are never discussed in Schirmer and Meurer. Though ignored by Schirmer and Meurer, these same physics become important when the combustor dimensions are scaled downward to the claimed dimensions Thus, the teachings of these references would not lead one of ordinary skill in the art to the miniature combustion chamber and process taught and claimed by the applicants. Pello Decl. at ¶ 8; Ronney Decl. at ¶ 8.

Turning specifically to Schirmer '118, the author does not mention the importance of heat loss and quenching. It is clear that he has not considered the scaling effects resulting in quenching since he prescribes the addition of air to quench the flame in the chamber thereby implying the non-existence of an important wall-quenching effect. Schirmer '118 indicates that there is substantial heat transfer to the chamber wall at column 3, lines 30—32 by noting that the chamber must have high mechanical strength and be resistant to elevated temperatures. Pello Decl. at ¶ 9; Ronney Decl. at ¶ 9.

It is also clear that Schirmer '118 is directed to larger-scale combustors than those taught and claimed by the applicants. For instance, at column 2, lines 18—20 Schirmer '118 indicates the presence of a "highly turbulent shear interface of the fuel and the air." It is common textbook knowledge that turbulence occurs when the Reynolds number, which increases in direct proportion to the length scale of the flow passage, is large, or the onset of turbulence in a fluid occurs only when the product of the velocity and the representative length dimension exceed a

threshold. Another indication that Schirmer '118 is directed to larger-scale combustors occurs at column 2, Lines 22—25, where velocities up to 250 feet per second are deemed allowable. In a chamber dimension of ten centimeters or less, this allows about a millisecond or less for combustion to occur which is usually too short a time to accomplish the vaporization, mixing of fuel vapor and oxidizer, and chemical oxidation processes which in totality and in sequence form the combustion process. Thus, Schirmer '118 clearly relates only to the physics that operate in devices on a scale much larger than those taught and claimed by the applicants. Pello Decl. at ¶ 10; Ronney Decl. at ¶ 10.

The statement at column 3, Lines 1-14 of Schirmer '118 regarding "self-regulation of the wall temperature" is not correct . That is, self-regulation occurs as applicants indicate by maintaining a stable liquid film on the wall. Schirmer '118 does not teach maintaining a stable liquid film on the wall. To the contrary, Schirmer '118 states at column 2, lines 11—22:

> Broadly speaking, my combustion apparatus permits the introduction of fuel uniformly onto the entire inner surface of the primary combustion chamber through a porous liner spaced from the inner wall of the chamber, and the introduction of air in the form of a vortex into the primary combustion chamber so that the flow of air spirals or swirls coaxially through the primary combustion chamber. Combustion apparently is effected at the highly turbulent shear interface of the fuel and the air. The shear interface, and therefore the combustion occurs near the surface of the porous wall and in the mixing zone.

It is common text book knowledge that at the prescribed flow rates of Schirmer '118, the shear forces would be such that the layer of fuel on the chamber walls will become unstable and break-up into droplets for vaporization and, thus, heat protection of chamber walls is lost. Pello Decl. at ¶ 11; Ronney Decl. at ¶ 11.

Turning to Meurer, it also does not address the issues of heat loss and quenching associated with smaller dimensions. Specifically, Meurer does not prescribe that the combustion

chamber wall should be fully or substantially covered by the liquid to reduce heat losses. Moreover, Meurer teaches cooling the combustion wall with air thus indicating an acceptance of heat loss to the walls. Scaling of Meurer would result in combustion failure due to quenching as a result. Pello Decl. at ¶ 12; Ronney Decl. at ¶ 12.

As for Schirmer '672, it addresses gaseous fuel and atomized liquid fuel only. As discussed above, simply scaling of Schirmer's device to the dimensions of applicants, and nothing more, would result in combustion failure due to quenching. Pello Decl. at ¶ 13; Ronney Decl. at ¶ 13. Thus, its combination with Meurer adds nothing to Meurer. Accordingly, claims 1-12 meet the requirements for patentability under 35 U.S.C. 103 in view of Schirmer '118, Meurer, and Schirmer '672.

Independent Claim 15 recites a combustion process that includes "forming and maintaining a liquid film over substantially an entire interior surface of the chamber" wherein the combustion chamber comprises "a lateral dimension transverse to a major flow direction within the chamber that is sub-centimeter." The Examiner rejected Claims 15-16 and 19-21 under 35 USC 103 as being unpatentable over Schirmer '118 and Meurer, and Claims 15 and 17 under 35 USC 103 as being unpatentable over Rao (US 4604988). Applicant respectfully submits that Claims 15-17 and 19-21 are not obvious in view of these references because neither of these references teach or suggest "forming and maintaining a liquid film over substantially an entire interior surface of the chamber" and, thus, cannot teach or suggest performing the combustion process in a sub-centimeter chamber.

As noted above, at the claimed dimensions, i.e., sub-centimeter lateral dimension, which are comparable to known quenching distances, the surface-to-volume ratio for the combustion

chamber is so large that a flame is typically not sustainable within the chamber due to the large heat transfer losses to the chamber walls. The dimensional aspects of miniature combustion chambers create different phenomena which prevent the principles of larger combustion chamber systems from operating in smaller, miniaturized combustion chambers. Pello Decl. at ¶ 5-6; Ronney Decl. at ¶¶ 5-6. Because these references do not teach forming and maintaining a liquid film on the entire or substantially the entire interior chamber surface, simply scaling the apparatus of these references to the claimed dimensions would result in combustion failure. Thus, the teachings of these references would not lead one of ordinary skill in the art to the miniature combustion chamber and process claimed in claim 15.

Turning again to Schirmer '118 at column 2, lines 18—20, Schirmer '118 indicates the presence of a "highly turbulent shear interface of the fuel and the air." It is common textbook knowledge that turbulence occurs when the Reynolds number, which increases in direct proportion to the length scale of the flow passage, is large, or the onset of turbulence in a fluid occurs only when the product of the velocity and the representative length dimension exceed a threshold. Another indication that Schirmer '118 is directed to larger-scale combustors occurs at column 2, Lines 22—25, where velocities up to 250 feet per second are deemed allowable. In a chamber dimension of ten centimeters or less, this allows about a millisecond or less for combustion to occur which is usually too short a time to accomplish the vaporization, mixing of fuel vapor and oxidizer, and chemical oxidation processes which in totality and in sequence form the combustion process. Pello Decl. at ¶ 10; Ronney Decl. at ¶ 10.

It is common text book knowledge that at the prescribed flow rates of Schirmer '118, the shear forces would be such that the layer of fuel on the chamber walls will become unstable and break-up into droplets for vaporization and, thus, heat protection of chamber walls is lost, which at the claimed dimension is fatal to combustion. Pello Decl. at ¶¶ 10-11; Ronney Decl. at ¶¶ 10-11.

As noted above, Meurer also does not address the issues of heat loss and quenching associated with smaller dimensions. Specifically, Meurer does not prescribe that the combustion chamber wall should be fully covered by the liquid to reduce heat losses. Moreover, Meurer teaches cooling the combustion wall with air thus indicating an acceptance of heat loss to the walls. Scaling of Meurer would result in combustion failure due to quenching as a result. Pello Decl. at ¶ 12; Ronney Decl. at ¶ 12.

Rao considers a situation in his vortex device where the liquid is not the fuel or a chemical reactant. Only heat transfer and no mass transfer occur between the liquid and the core gas flow. Rao prescribes a method and apparatus for contacting a flow of heated gas with a flow of liquid to form a mist. The class of devices discussed in Rao certainly does not include combustors and, moreover, would not teach or suggest forming and maintaining a liquid film on the interior surface of a sub-centimeter combustion chamber to affect combustion therein. Pello Decl. at ¶ 14; Ronney Decl. at ¶ 14.

In addition to the nonobviousness arguments presented above, the pending claims are not obvious because there is a long felt, but unsatisfied need to produce highly efficient miniature combustion chambers. Pello Decl. at ¶ 15; Ronney Decl. at ¶ 15. Highly efficient miniature combustion systems could be used in the growing number of devices that are of reduced size.

These devices require a energy source with a power density which is greater than current rechargeable batteries. The present invention discloses such a system and tends to reduce the possibility of quenching of the flame. Other miniature combustion chambers have not solved the problems created by the high surface-to-volume ratios which result in high heat transfer losses and flame quenching. As disclosed, the present invention solves the quenching problem to create a highly efficient miniature combustion chamber. Further, the present invention allows the use of typical hydrocarbon fuels. Other miniature combustion chambers require substitution of hydrocarbon fuels for quench resistant fuels such as hydrogen gas.

Accordingly, because the prior art fails to teach, suggest, or disclose all of the elements of the claimed invention and because there is a long felt, but unsatisfied need to produce highly efficient miniature combustors, Applicant respectfully submits that Claims 1-12, 15-17, and 19-21, as well as new claim 24 and 25 which depend from claim 15, meet the requirements of patentability and are in condition for allowance.

Conclusion

Applicant submits that the claims are in condition for allowance. Should the Examiner have any questions regarding this Amendment, he is invited to call the undersigned attorney at (949) 567-6700.

Respectfully submitted,

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